COLD FIELD ELECTRON EMITTERS BASED ON SILICON CARBIDE STRUCTURES

CROSS REFERENCES TO RELATED APPLICATIONS

[0001] This application claims priority upon U.S. provisional application Ser. No. 61/589,954 filed on Jan. 24, 2012.

FIELD

[0002] The present subject matter relates to a monolithic and porous silicon carbide field electron emitter, and particularly a cold field electron emitter, and related methods of forming.

BACKGROUND

[0003] Cold field electron emitters or "cold cathode" electron sources based on field emission have been continuously researched for decades, with resurgence in recent years motivated by advances in carbon nanostructures. This research is motivated by the significant technological applications enabled by the desirable properties of field-extracted cold electrons in comparison to heat induced electron emissions. The use of carbon nanotube field emitters in display applications and its potential advantages have been known for some time. In addition though, attributes such as minimal beam spread and fast response would also allow for advances in other critical applications, including microwave electronics and x-ray sources. These attributes would lead to superior communication and radar, and new functionalities and modalities in imaging technology for medicine and security. These latter applications, however, require an emitter capable of high emission current, which so far has been in the realm of thermal sources.

[0004] Accordingly, a need exists for a cold field or "cold cathode" field emitter which could provide relatively high emission current densities without failure. Moreover, it would also be beneficial to provide methods of forming such emitters at ambient temperatures and which are amenable for large scale manufacturing processes.

SUMMARY

[0005] The difficulties and drawbacks associated with previously known technologies are addressed in the present products and methods for a silicon carbide cold field emitter.

[0006] In one aspect, the present subject matter provides a method of forming a monolithic, homogeneous, and porous silicon carbide field emitter having a plurality of discrete emission projections extending from a face of the field emitter. The method comprises providing a silicon carbide substrate of any poly-type. The method also comprises providing an anodizing solution including (i) at least one reducing agent, (ii) at least one oxidizer, and (iii) water. The method additionally comprises electrochemically etching a face of the silicon carbide substrate with the anodizing solution for an effective period of time to thereby form an etched silicon carbide substrate that is porous and maintains structural integrity. And, the method further comprises subjecting the face of the porous silicon carbide substrate to ion etching to thereby form a silicon carbide field emitter having a shaped macroscopic surface, in the form of fins, pillars, or other structures, whereby the shaped surface leads to increased emission through additional field enhancement. The shaped surfaces have a plurality of discrete emission projections extending from the face of the field emitter.

[0007] In another aspect, the present subject matter provides a porous silicon carbide field emitter having a plurality of discrete emission projections extending from an emission face of the field emitter. The field emitter is monolithic and homogenous in a direction transverse to the emission face of the field emitter.

[0008] In still another aspect, the present subject matter provides a cold cathode silicon carbide field emitter that defines an emission face having a collection of discrete emission projections. The field emitter achieves an emission current density greater than 6 A/cm^2 at an applied macroscopic electric field of 7.5 V/μm.

[0009] As will be realized, the subject matter described herein is capable of other and different embodiments and its several details are capable of modifications in various respects, all without departing from the claimed subject matter. Accordingly, the drawings and description are to be regarded as illustrative and not restrictive.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. **1** is a scanning electron microscopy (SEM) image of a porous silicon carbide substrate having a plurality of pillar projections, in accordance with the present subject matter.

[0011] FIG. **2** is a SEM image of a porous silicon carbide substrate having a plurality of fin projections, in accordance with the present subject matter.

[0012] FIG. **3** is a SEM image of the fin projections of FIG. **2** at a greater magnification.

[0013] FIG. **4** is a planar view of a SEM image of an electrochemically etched "C-face" of silicon carbide substrate formed using a set of conditions referred to herein as Condition **1**.

[0014] FIG. **5** is a planar view of a SEM image of an electrochemically etched "C-face" of silicon carbide substrate formed using a set of conditions referred to herein as Condition 2.

[0015] FIG. **6** is a graph of current density versus electric field for the silicon carbide substrates produced using Conditions **1** and **2**, and for an unprocessed silicon carbide wafer.

[0016] FIG. **7** is a Fowler-Nordheim plot of emission from the silicon carbide substrates produced using Conditions **1** and **2**.

[0017] FIG. **8** is a SEM image of a porous silicon carbide substrate having a mesa projection, in accordance with the present subject matter.

[0018] FIG. **9** is a SEM image of a porous silicon carbide substrate having a plurality of fin projections, in accordance with the present subject matter.

[0019] FIG. **10** is a SEM image of a porous silicon carbide substrate having a plurality of pillar projections, in accordance with the present subject matter.

[0020] FIG. **11** includes graphs of current density versus electric field and a Fowler-Nordheim plot for the mesa projection of FIG. **8**.

[0021] FIG. **12** includes graphs of current density versus electric field and a Fowler-Nordheim plot for the fin projections of FIG. **9**.

[0022] FIG. **13** includes graphs of current density versus electric field and a Fowler-Nordheim plot for the pillar projections of FIG. **10**.